REPORTS

Of the IAP Science Education Program

Developing IBSE: New Issues

The roles of assessment and the relationship with industry

A global conference

HELSINKI, FINLAND, 30 MAY-1 JUNE 2012

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the global network of science academies

The IAP Science Education Program

IAP is a global network of science Academies. Launched in 1993, it counts 104 Academies in 2012 throughout the world. Since 2003, IAP has developed a science education program (SEP) under the guidance of Jorge Allende (Chile). The program is currently (2012) led by a Program Council, with 12 members, and acts in four regions, namely Africa, the Americas, Asia-Pacific and Europe, where science Academies are carrying a number of actions. The program holds a biennial Conference to discuss fundamental issues related to the implementation of *Inquiry Based Science Education* (IBSE) in primary and secondary schools. The Conference also gives to the participants an opportunity to meet and exchange practices and ideas about national or regional science education pilot or large scale projects. The present document results from the 2012 Conference held in Helsinki (Finland) with over 100 invited participants. The 2014 Conference will be held in China. Regional conferences and workshops are also organized by the Regional branches or national Academies.

The 2012 York Conference received an excellent support of Wellcome Trust, a UK charity, which is gratefully acknowledged and thanked by the organisers.

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Conference opening

Armi Mikkola, Counsellor of Education
Ministry of Education and Culture
Department for Higher Education and Science Policy

Opening the conference, Armi Mikkola, Counsellor of Education Ministry of Education and Culture Department for Higher Education and Science Policy of Finland, said that the timing of Helsinki hosting the conference could not be better, as Finland was currently finalizing a reform in the distribution of lesson hours in basic education. This gave Finnish participants an interesting and valuable opportunity to engage in discussion on the development of teaching and researching with international experts in the teaching of science. At the threshold of the reform of basic education, much discussion has taken place on the competence needs of tomorrow, and this discussion is likely to continue in the near future. Mrs Mikkola indicated that guidelines for a positive future for the young people of Finland and, at the same time, for the whole nation, were being created. Reforms in the distribution of lesson hours and the curriculum are carried out in Finland approximately once in ten years, which means that the decisions to be made now will extend their impact long into the 2020s.

This is why right now, Finnish policy-makers in education are considering what will be essential and necessary competence in the next decade. What type of knowledge, skills and capabilities are needed to act as an active citizen and a competent employee? What are the capabilities required by higher education levels? How do we support the opportunities of young people to get the competence needed in the society and working life of tomorrow? How are creativity and critical thinking developed?

These questions are currently being discussed in Finland.

Mrs Mikkola added that she was pleased to note in the conference programme that the issues of student assessment were addressed from a variety of different angles in the contents of the conference. This drew her attention because the questions of student assessment often appear as problematic in the interviews of teachers. Student assessment is a demanding task and an aspect of teaching for which it seems there is not always enough time in teacher education. Many recently graduated teachers mention this as an area in which they would require more training. Armi Mikkola concluded by saying she believed that the broad expertise represented by this conference would produce a great deal of new and significant information on student assessment to be utilised in teacher education, in research concerning teacher education and in continuing education for teachers and in schools.

Our role in inventing the Future

Ana Costa Freitas
Advisor Chief Scientific Advisor Office
Bureau of European Policy Advisers - BEPA
European Commission

Then Ana Costa Freitas, Advisor Chief Scientific Advisor Office Bureau of European Policy Advisers in the European Commission considered the contribution of Europe to meeting global challenges, by raising two main and closely related questions: how do we see the future now? And why do we need to invest on it?

She presented the Europa 2020 strategy, centred on Science and Education, as the main tool of the European Commission to address these global challenges, complemented and supported by the new Multiannual Financial Framework (MFF) 2014-2020.

She stressed the importance of building the future on Europe's three main current assets, i.e. "smart brains", "Great science infrastructures", and "Appropriate funding instruments (Horizon 2020; Erasmus for All)".

According to her, unleashing Europe's potential of growth by cashing in on those assets requires to:

1. Invest in young generations: in 2020, 20% of Jobs in Europe will need Higher Education and there is a lack of Science and Technology Graduates.

2. Believe one can make it: all the elements needed to get Europe out of the current economic crisis and back on a path of growth are in the Europa 2020 Agenda and the new programs. One just has to grasp the opportunities.

3. Use one's strengths to the maximum: Europe should speak with one voice at the global level to make itself heard. For this to happen, one needs to act jointly.
Our diversity has to be our power.

She concluded by a stimulating punch line: Europeans need to speak up, stand up and gang up.

Keynote speech

Inquiry Based Education for all

Prof . Dato Lee Yee Cheong, UNESCO, ISTIC, Akademi Sains, Malaysia

Then, "In his key-note address Prof. Dato Lee Yee Cheong, UNESCO, ISTIC, Akademi Sains, Malaysia pointed out the contribution that IBSE can make to the twin challenges of global poverty and global climate change. He saw these problems are overhung by the growth of world population increasingly mesmerised by mass media to consume beyond its means and at the same time overstressing the resources of the planet earth. Indeed, he reminded that according to estimates, at the consumption level of the current world population of 7.0 billion, humans are already consuming the resources of 1.5 earths. He added that the prospect was for the world population to reach 9.5 billion by 2050, all striving to grow economically through more consumption. He suggested that the solution was to extend the philosophy and practice of IBSE to all children so that we develop a global citizenry that will have a culture of sustainable consumption based on hard evidence and not media propaganda: hopefully, today's children would lead their world to a sustainable future.

IBSE: the roles of assessment and the relationship with industry: a reflection

by Derek Bell

In the first decade of the 21st Century science education and the related disciplines of technology, engineering and maths (STEM) have become inextricably linked to the future well-being and prosperity of the global economy and society. National governments are striving to improve the competitiveness of their countries and, with few exceptions, are emphasising the key role STEM industries have in helping them to achieve their goals. This in turn has increased the pressure on education systems to raise standards across the board but in particular those in science and mathematics in order to meet the future demands for more well-qualified scientists, technologists, engineers and mathematicians. In addition to the need for more people to go into STEM careers there is an increasing recognition that everyone should have a better understanding of the ways in which STEM impacts on all aspects of their lives and the contribution that it has made to the societies and cultures in which they live. It can be argued therefore that the pressure on science education has never been higher.

On the one hand it is claimed that the standards of education are rising and that there are increasing numbers of young people leaving education with higher qualifications. On the other hand, criticisms from business and industry about the lack of good quality young people coming into the work force remain a frequent occurrence. Too often the debate becomes detached from reality through a lack of understanding, on both sides, of what is a very complex and variable situation. Too many generalisations are made with little regard for the evidence that is available and with little appreciation of what is a changing landscape. Against this background, it should not be surprising that the twin themes for this IAP conference – the roles of assessment and the relationship with industry – both have a contribution to make in moving the debate forward.

This short section of the conference report endeavours to draw out common threads of the discussions which link the two themes. It will highlight some points of agreement as well as areas for further deliberation and action.

It should be noted that, while the context for the conference discussions was principally that of education 3 to 18 years, the majority of the issues are also debated in relation to higher education and vocational training contexts. Most importantly it must be remembered that the majority of young people do not progress to university from school but that high quality science education should be available for ALL young people appropriate to their needs.

1. The importance of dialogue

Fundamental to all the discussions before, during and after the conference is the importance of learning across a range of different situations and contexts. At one level this is working with young people to improve their scientific understanding and capabilities. Whilst at another level it is about how different communities or sectors (e.g. education and industry, academic and vocational, public or private) learn to work together more effectively to achieve shared goals. Whatever the circumstances, the importance of dialogue in the process of learning and building of relationships cannot be emphasised too highly. As Paul Black, with acknowledgement to Robin Alexander, suggested “talking is arguably the true foundation of learning.”

There are examples of some strong relationships between education and industry but too many are being conducted in isolation. There is an urgent need, as Alexa Joyce pointed out in her presentation, to create more land-bridges not only to share good practice but, more importantly to extend and deepen the dialogue between the different parties in order to gain a better shared understanding of intended objectives. Anders Hedberg in his background paper and presentation offered one model for consideration arguing that “a particularly valuable result … is the increased mutual understanding of professional cultures and values that characterize the business and education environments. …. [and] …. comprehending what challenges their partner faces, and how they anticipate, meet and overcome them.”

The key challenge is to establish more effective ways of encouraging such productive dialogue between the different parties in order to establish a shared understanding of the goals and requirements of education and industry.

2. A common purpose for science education

The starting point for much of the discussion on assessment was a call for a clear statement of the purpose of education in general and science education in particular. Only with such a clear and agreed statement is it possible to begin to decide:

- What should be assessed?
- Why it should be assessed?
- Whether or not it can be assessed?
- How could / should it be assessed?
- Who should carry out the assessment?

All of these issues were considered and, as was eloquently argued and demonstrated by Jens Dolin in his presentation, different approaches to assessment can produce different outcomes in terms of performance. Other contributions highlighted how assessment approaches too often do not extend beyond assessment of subject content or reflect the needs of the workplace.

After spending two days of discussion broadly agreeing that assessment needs to be able to reflect and report on a wide range of attributes relating to what young people know, understand and can do, it was almost a revelation when Marita Aho presented a very similar list of what employers wanted from prospective employees. This is young people who can:

- think critically for themselves;
- solve problems using innovative and imaginative approaches;
- work independently and as part of a team as necessary;
- communicate effectively through different forms of media;
- develop good interpersonal relationships;

- adapt to changing circumstances.

It was suggested that the work place of the 21st Century is changing rapidly (and maybe education is finding it difficult to keep up), working life is becoming less routine, fewer tasks are performed in isolation and solutions are reached via multiple approaches. All this requires new forms of leadership and management working in partnership with employees who are flexible in the way they relate to others and to information in all its forms. They need to be curious, alert and able to understand issues such as risk, reliability, validity, and the relevance of information.

Science education has much to offer in meeting these needs but it does not have a monopoly and, through its curricular and assessment systems, often fails to do justice to the development of the 'soft skills' which employers are so often looking for.

It would appear that there is considerable agreement as to the purpose and potential of science education to prepare young people for work both in science and in other disciplines. Two key issues can be identified from the discussions that need to be addressed:

- Despite the obvious common ground, there remains a lack of shared understanding of responsibilities of different sectors. No education system can produce young people matched to specific jobs in particular industries, therefore there is a responsibility on employers to undertake the specific training that is required by them. However an education system should be able to prepare young people better to take on the demands of the workplace (wherever it is). Thus there is much to be done to explore ways in which the responsibilities of education and employers can be met more effectively.
- The major approaches to assessment / examinations in many countries do not actually assess the characteristics that are considered important by both the education community and are wanted by industry. As Wynne Harlen states in her summary, "In order to assess the competences and understanding that we strive to help our students develop, students must be engaged in situations where they have to use these competences and apply their knowledge." Achieving this situation would make a strong contribution to meeting the expectations that employers have for potential employees and IBSE has a key role to play.

3. The contribution of an IBSE approach

The characteristics of IBSE approaches strongly support the development of young people who are able to think for themselves, are capable of taking responsibility for their learning and have the wider range of skills listed above. IBSE is not all encompassing but, from the discussions during both themes of the conference, it is clear that IBSE has a key contribution to make in preparing young people for life in general beyond the classroom and for the workplace in particular. The discussion can be sharpened by posing two questions:

- from an education perspective: How might IBSE better prepare young people for the world of work?
- from an industry perspective: How might IBSE better meet the needs of employers?

It is important to be clear that preparing young people specifically for employment is not the sole purpose of education but it is certainly a major element. As Guillermo Fernandez reminded us by quoting Bruce Alberts, "IBSE precisely fits the needs for workforce skills that have been widely expressed by business and industry." Thus it can be argued that developing IBSE approaches to science education not only improves the quality of the educational experience for young people but also makes a major contribution to meeting the expectations and needs of employers.

IBSE approaches do not ignore the importance of knowledge and understanding of scientific concepts but raise the profile of the wider aspects of scientific enquiry, the very qualities that produce good science and what employers want. For example, science inquiry is based on intrinsic curiosity, inquisitive attitudes and aptitudes and a willingness to work collaboratively; exactly the qualities employers are asking for. More fundamentally the values of science such as respect for evidence, the search for the 'truth', perseverance and reliability are also values that underpin good business practice.

In short IBSE has a major contribution to make in preparing young people for the world of work and for meeting the needs and expectations of employers. The key issue is the need to articulate this more clearly, possibly through exemplars drawn from a range of different contexts.

4. Using Assessment

Employers have an interest in high quality reliable and valid assessment of young people's achievements and capabilities. They need to know and understand what is being assessed and what the results of that assessment represent in terms of the individuals who present themselves as potential employees. In order to match candidates with jobs, employers need to be familiar with what achievements and qualities are being assessed whether they are part of a suite of qualifications or set out in narrative form as part of a reference. Employers must have confidence that the assessment outcomes are comparable so that they can make judgements as to the capabilities of one candidate against those of another.

Thus the major use employers make of assessment and its outputs is to measure and make judgements about the suitability of individuals for particular jobs, in essence a use that is almost exclusively summative. In contrast the major use of assessment in education is, or at least should be, to improve learning so that it better prepares young people for their life beyond school. Thus the use is predominantly formative. The different purposes to which assessment is put by the different groups are not incompatible but the distinction is rarely acknowledged in the general debate, often media driven, of standards in education and the quality of students leaving the school system.

The fundamental point that arises from the discussions is that both education and industry rely on good quality assessment that is fit for purpose. It is therefore essential that both sides better articulate their requirements and work together so that assessment programmes better reflect the full-range of learning outcomes that meet the objectives of education and the expectations of industry. The key issue is not only the development of more suitable approaches to assessment, including peer and self-assessment, but also ways of reporting the outcomes clearly and succinctly.

Final thoughts

In summary the key messages that can be drawn out from a consideration of the two themes are:

- dialogue is the foundation for learning and building strong relationships; it is important within communities but is doubly important between communities such as education and industry;
- there are many things that education and industry have in common, especially in terms of the desired qualities to be developed and demonstrated by young people;
- IBSE approaches can make a significant contribution to preparing young people for work and in meeting the needs of employers;
- the uses of assessment may vary but the fundamental requirements of assessment – valid, robust, consistent and reflecting the full range of learning outcomes – remain the same.

Although these areas provide a positive basis on which to move forward, progress is not without its challenges. The first is the need for a wider acceptance of the points of agreement, such as those above, and a greater appreciation of the different perspectives that are brought to discussions and projects. There is undoubtedly a desire from both education and industry to work more closely together and there are many examples of good partnerships. A second key challenge is to establish mechanisms by which good practice can be expanded, deepened and sustained. This will require using existing networks as well as building new ones. The IAP network with its support for IBSE and its international links and relationships beyond academia is in a position to make a key contribution to such developments.

Theme 1: Student assessment and IBSE

Introduction
The roles of student assessment in IBSE

Wynne Harlen

In her introduction to the 1st theme, Wynne Harlen stressed that there were many good reasons for implementing inquiry-based science education (IBSE) but whether or not this happens depended on a number of factors, one of which was the focus of the first theme of the conference – student assessment. She said that what is assessed had a strong influence on the curriculum and pedagogy, so if students are to have the opportunity to achieve the understanding of science and of scientific activity through inquiry – the goals of IBSE – then assessment must reflect the full range of these goals, including attitudes and competences. She observed that the impact of assessment was increased when results of summative tests were used for high stakes decisions that affect individual students or for accountability of teachers and schools. She added that it was increasingly the case, since governments needed to see that the resources that certainly needed to be committed in order to change practice in schools were indeed producing the intended results.

She proposed a definition of assessment as the process of collecting evidence and using it to make inferences about what students know and can do. She said it could have a useful role in making learning goals explicit, in terms of things that students were expected to be able to do. However if we relied on traditional assessment (and it is the exception for assessment to truly reflect the goals of IBSE) this was likely to act as a brake on the spread of IBSE practice.

She reminded the definition of IBSE developed by the IAP science education programme (included in the report of the conference held in York, England in October 2012), which refers to 'students progressively developing key scientific ideas through learning how to investigate and build their knowledge and understanding of the world around'. This implies that in order to assess the competences and understanding that we strive to help students to develop, students must be engaged in situations where they have to use these competences and apply their understanding. But as well as this summative assessment of what has been learned, there is a role for assessment in the process of learning, described as assessment for learning or formative assessment.

Wynne Harlen then exposed some clear differences between formative and summative assessment. Formative assessment involves the collection of evidence about learning as it takes place, the interpretation of that evidence in terms of progress towards the goals of the work, the identification of appropriate next steps and decisions about how to take them. It helps to ensure progression in learning and regulates the teaching and learning processes to ensure learning with understanding, by providing feedback to both teacher and students. Summative assessment provides information used to make inferences about achievement of learning goals at particular times, usually at the end of a topic, course or stage of schooling. Data for summative assessment can be collected in a variety of ways, such as by testing, summarising observations made by the teacher (for formative assessment), reviewing a portfolio of students' work or embedding special assessment tasks in regular work. However, she also said that the distinction between formative and summative assessment was not clear-cut. It is not a matter of the kind of information gathered or how it is gathered, but rather how it is used. So the collection of summative data during the year can be used to inform the teacher of the areas of more and less progress of students and enable action to be taken to help learning. Indeed there are good reasons for arguing that all assessment should ultimately help learning.

Theme 1a: Formative assessment and its relationship with summative assessment.

Practices, Principles and integration of Formative and Summative Assessment

Student assessment has taken an increasingly prominent role in education policy in OECD countries. This includes both “formative” and “summative” assessments.

- Formative assessment refers to the frequent, interactive assessment of student progress to identify student progress. Teachers are then able to adapt teaching to better meet learning needs. Formative assessment also emphasises the importance of actively engaging students in assessing their own learning – thus developing skills for “learning to learn”.

  The contribution that their oral and written work makes to the development of students as effective learners can be further enriched if they are involved in group discussions in which they assess one another’s work. This helps both understanding of the criteria by which such work should be judged, and, through comparing his/her work with that of fellow students, each student’s capacity for self-assessment. In this, as in oral dialogue, students are resources for one another.

- Summative assessments refer to tests that provide a summary judgment of student performance. In many countries, these assessments track school and student performance in meeting centrally defined goals for learning.

  Such tests can serve a dual purpose. Insofar as students are given feedback, or assess their test answers in peer-group discussions, it serves the formative purpose, as a review of the learning and as an opportunity to identify and correct gaps in the learning. The teacher can also mark or grade each student’s work and as such records are built up over time, they can serve the second main purpose of assessment, the summative. In this way, students and teachers can come to see summative tests as contributions to learning.

  Summative tests can only serve this purpose effectively if they reflect the full range of learning aims. Formal written tests cannot do this, particularly in the area of inquiry-based learning. So teachers must play a part in such assessment, because only they can observe and judge their students over a wide range of activities and over extended time. Such involvement it not encouraged in most national systems: teachers’ judgments are not trusted. What is needed is sustained programmes of professional development so that teachers can develop and demonstrate the skills in assessment that can command public trust.

Educators and assessment experts have suggested that formative and summative assessment should be more closely integrated so that data from national/regional assessments may also be used to shape classroom teaching and learning. In turn, classroom-based formative assessments could provide valuable data on school and student performance to better target groups of students in need of additional resources.

Currently, however, there are important technical barriers to the integration of summative and formative assessment. Typically, data gathered in large-scale national and regional assessments are not at the level of detail needed to diagnose individual student needs, nor are they delivered in a timely enough manner to have an impact on the learning of students tested. There are also challenges related to creating reliable measures of higher-order skills emphasised in standards and curricula, such as problem solving and collaboration (skills that are important for inquiry-based science education). Moreover, no single assessment can provide sufficient information on student learning.

Ongoing research and development aimed at improving testing and measurement technologies aims to address these barriers. Many of these rely on ICT, such as:

- Technology-based assessments incorporating simulation, interactivity, collaboration and constructed response formats. For example, students may potentially use the multi-media functions of ICT to show how they would perform a physics experiment or some other problem-solving task.
- Internet-based programmes allowing students to "predict-observe-explain" specific concepts, or to develop concept maps using online tools to show their understanding of processes.
- ICT-based games to assess student learning, while also motivating students to engage in problem solving.

ICT-based assessment would potentially provide feedback on student performance in real time, and at the level of detail necessary to identify any specific learning needs. Data from groups of students could also be aggregated so that policy makers could get a clearer picture of how well different groups of students are performing (e.g. students who are at risk of drop out; girls versus boys; and so on) and where additional resources may be needed.

Systems may also strengthen the links between formative and summative assessment by ensuring that national and regional assessments measure higher order skills taught in classrooms; ensuring that teachers' assessments of student learning are counted alongside national/regional test results; creating test banks so that teachers may assess student "on demand" – and providing additional data on student learning for monitoring purposes.

Integration of formative and summative assessment will provide both policy makers and educators with much richer information, and better insight regarding the effectiveness of teaching, including higher-order skills involved in inquiry-based science education.

Diagnostic assessment prior to instruction should also be considered in its link with instructional strategies and formative assessment.

Theme 1b: Approaches to summative assessment of IBSE

The problematic use of tests as a measure for inquiry competences

Jens Dolin, head of Department of Science Education, University of Copenhagen

Inquiry-based science education should promote scientific literacy and science competences, as they are described in most IBSE projects. These competences are generally more complex than described in traditional curriculum goals and a valid assessment of them is a necessary prerequisite for improving teaching and learning with an inquiry approach. But most testing systems are not able to capture such learning outcomes. Due to limited resources and a simplistic understanding of learning and science, they are often restricted to relatively simple drill and multiple choice questions. The international PISA test claims to be an exception. PISA is not a curriculum test but is testing literacy: "knowledge and skills needed in adult life", i.e. close to the expected outcome of an inquiry oriented science education. But it is a test performed as a traditional written test taken in a situation very far from what you could call "adult life" and with no possibility for assessing practical skills, science processes, dialogical processes and other competences often linked to inquiry approaches. At the same time the PISA test have a large influence on the Danish educational system, as it has on most countries participating in the test. It dominates the public discourse about student performance and teacher proficiency and it provides the politicians with arguments for dramatic changes in a hitherto well established and commonly appreciated national educational system. In Denmark the PISA results have been used as an argument for a back to basics trend with more teacher-centered teaching and more emphasis on standard content knowledge. It is therefore important to investigate to what degree the PISA test and its results can justify such changes. Does the PISA science test give a valid picture of Danish students' scientific literacy? Is it a suitable tool for changing the Danish science education? To answer these questions we (I and Lars Brian Krogh from University of Aarhus) have re-tested, in a more school-like, everyday setting, students who have completed the PISA test. Through a relatively complex methodological design, we were able to compare student performance in the two different situations, using PISA's own standard, and at the same time get a broader knowledge of the students' science competencies than the PISA test makes possible.

The theoretical basis is research showing that student performance is dependent of the mediation in the situation (available artifacts, possibility for dialogue with peers, a relaxed atmosphere etc.) and that any assessment implies a model of learning. The PISA test, like all large scale tests, is based on a post-positivistic approach to learning, seeing student abilities as constant across different assessment situations. Our assessment is more socio-cultural, where student abilities are seen as dependent of/linked to the assessment situation. The differences in student performance in the two tests were quite dramatic: Changing the test-format to a more rich one increased students' overall performance on PISA-criteria from a mean of 0.54 to an interval 0.68-0.7 – an increase of 26%! And low performers improved relatively the most. A (traditional) psychometrician would say: 'The socio-cultural oriented test is easier for the student', while a socio-culturally oriented researcher will say: 'Knowing is in context and relative to circumstance'. More interesting was that the students only had a correct understanding according to the Danish learning objectives on 20-35% vs 45-75% correct PISA scores. They were thus able to perform mediocre in PISA science with only a very low fulfilling of the Danish curriculum. So, changing the test-format improved scores on PISA-tested knowledge areas and demonstrated that PISA is not able to capture advanced levels of scientific literacy (like those demanded in the Danish curricular goals); and students with a poor or incorrect understanding were able to perform well on PISA. And maybe the most important: A lot of relevant knowledge about student competence is not tested by PISA, thus missing didactical directions for improving science education.

These results are a warning of using test results from traditional tests as indicator for student competence within an inquiry based science education context. And they demonstrate the necessity of developing assessment formats able of capturing such learning goals in a reliable way.

Process Skills or Cognitive Endeavour? What makes a valid assessment of inquiry science?

Dr. Christine Harrison, King's College, London

When students carry out inquiry work they need to develop a range of process skills in order to investigate effectively. Equally they may utilise their reasoning skills to work out what is happening in their investigation and what that tells you about relationships and specific phenomena. This session will look at the validity of inquiry-based science and question what emphasis teachers should put on investigative work in the curriculum.

Theme 1c: Current initiatives in IBSE students' assessment

IBSE in Pakistan: Issues in Implementation and Students' Assessment

Manzoor H. Soomro and Abdul Rauf
Pakistan Science Foundation (Ministry of Science & Technology)

Pakistan Science Foundation (PSF), a Federal Government Organization under Ministry of Science and Technology, was established in 1973 through an act of the Parliament for promotion, popularization and funding of S&T research having bearing on socio-economic needs of the country. PSF [www.psf.gov.pk] has two subsidiary organizations viz; Pakistan Museum of Natural History (PMNH) [www.pmnh.gov.pk] and Pakistan Scientific and Technological Information Centre (PASTIC) [www.pastic.gov.pk] and a Science Wing for execution of its statutory functions.

Pakistan, being a thickly populated country, with most of its population in rural areas needs enhancement of science popularization programs and initiation of new techniques for attracting the youth towards science. The overall literacy rate (10 years & above) was 57.7 percent in 2009-10 (Pakistan Labour Force Survey, 2010). There were only 53,621 researchers in S&T sector in 2009 (PCST Survey, 2009). The Low literacy rate and extremely scientific manpower reflect the need of in-depth renewal of Education System of Pakistan. Pakistan Science Foundation (PSF) has been given the mandate, under S&T Policies of Government of Pakistan to create science awareness at grass root level. Recently, the responsibility of Education has been shifted to the Provincial Governments [under 18th amendment in the Constitution] which demands PSF, being a Federal Government body, to take action for improvement of science education by introducing new teaching methodologies in Pakistan with emphasis on Inquiry Based Science Education-IBSE.

In December 2010, PSF and Academie des sciences France signed MoU, mainly for conducting joint activities such as conferences and workshops on IBSE for promotion of science education in Pakistan. Accordingly, Experts from Academie des sciences France, with the support of Embassy of France in Pakistan conducted three training workshops on La main a la pate-LAMAP for Pakistani Teachers and Learning Facilitators of PSF Science Caravans in the years 2010-2011. Schools were selected through education authorities like Federal Directorate of Education, Private Schools Network, Education Trust Nasra etc. Preference was given to the schools of outskirts areas of Islamabad/Rawalpindi, as in a few of the schools of urban areas, the IBSE approach is already being used in one form or the other. Sixty (60) teachers and learning facilitators from 25 schools and nine (9) Science Caravan units were trained.

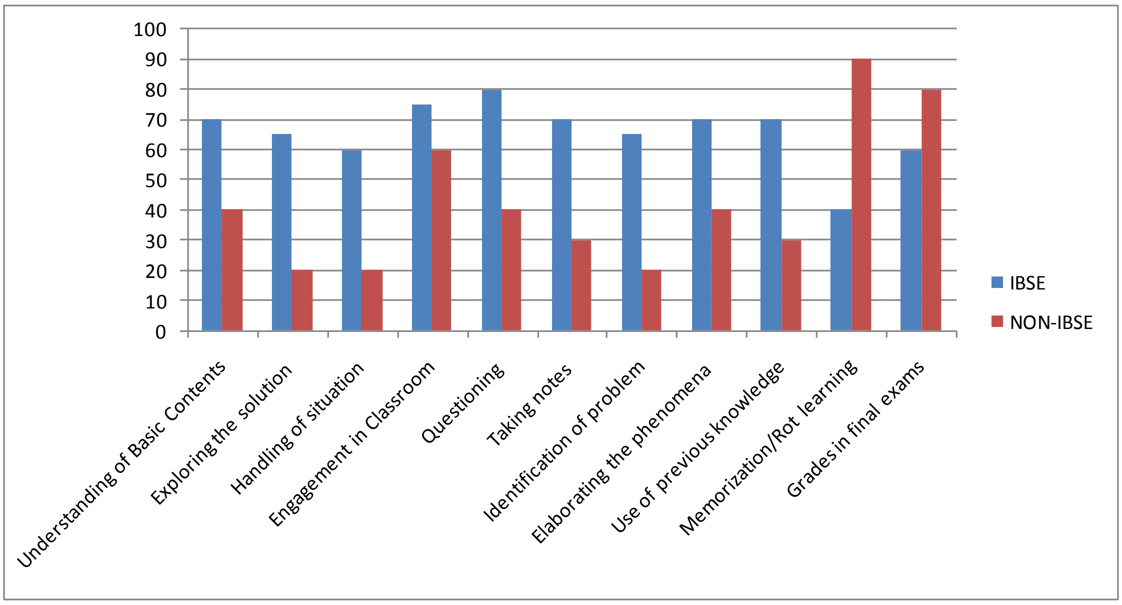
LAMAP in Pakistan is relatively new [hardly 1 ½ years old]. Even the teachers, nominated by their authorities who willingly come to participate in the IBSE-LAMAP workshops, are reluctant to adopt the approach and also facing problems in applying the La main a la pate in class rooms due to a number of reasons, including the following;

Formative Assessment in Conventional Pakistani system is carried out by means of monthly tests, Weekly Tests, Sudden tests, home assignments, and oral questing during classes. Grades are awarded on the basis of paper pencil tests and not on the basis of pupils' skills, which promotes Rote Learning and memorization instead of skill development.

ASSESSMENT:

To assess the students learning by LAMAP approach, Questionnaire was designed on 5 point rating scale. Statements were constructed to assess the learning parameters like Knowledge (Cognitive Domain), Skills (Psychomotor Domain) and Attitude (Affective Domain) and five Es i.e., Engage, Explore, Explain, Elaborate, Evaluate.

Data from 48 teachers was collected about the students' achievements by using LAMAP versus Conventional methods of teaching. They gave their feedback about 1250 students' learning using IBSE approach in the classrooms for 1 ½ hrs per week.



To get the information about students' achievements through LAMAP, PSF used various techniques for formative and summative assessment including the following;

- Review Meetings for Teachers and students
- Students Interviews
- Feedback from Teachers through Questionnaire and Data Analysis
- Monitoring of Science Club activities
- Visit of the LAMAP associated schools by PSF officials
- External Assessment by Experts from Teacher Training Institute (NISTE)

LESSONS LEARNT/RECOMMENDATIONS

- Teacher Training workshops in consultation with Teacher Training Institutes
- Involvement of Policy makers for Implementation of IBSE through National system of education, PSF is highlighting the need through wide media coverage.
- Exploring the funds from Government, Donors and Industry, as IBSE in turn can give them skilled manpower.

Using Scientific Tools for Formative Assessment and Development of On-line Assessment

Wei Yu, Research Center of Learning Science, Southeast University, Nanjing, China

The Pilot Project “Learning By Doing (LBD)” is an Inquiry Based Science Education and Learning in Kindergartens and Primary Schools (5-12years) in China which has been co-initiated by Ministry of Education and China Association for Science and Technology in Aug. 2001, aimed at promoting the children’s science education as well as their holistic development and wellbeing. After 10 years’ practice, LBD reach out to 22 provinces and benefiting over 200,000 students and Thousands teachers. LBD has become a sound foundation for revising the National Standard of Science Education in Primary Schools and promoting the national policy changing on early child development. LBD has got Purkwa Price in 2006 and the First Class Award of Education Research from MOE, China in 2010.

The unique character of LBD is to apply the research of Neuroeducation to IBSE. Just one year later to initiating LBD, in 2002 Research Center of Learning Science has been founded in Southeast University. The cross-disciplinary research on IBSE and Neuroeducation not only can support the pedagogy of IBSE but also create scientific tools applying to measuring learning outcome in classroom practices. Four series of instruments and software are being developed in our center: (1) Multiuser On-line Formative Assessment and Record System. The system can provide the response opportunity to over 40 users (students or teachers in training, see the attached picture), trainer can record the answers from all learners at same time and analysis it on-line. (2) Measuring Empathy and Communication Behavior System. Beside the traditional questioners and classroom observation, the physiological signal measuring and face recognition technology have been used in a coordinating way. (3) Evaluating Executive Function System. Virtual reality created by computer and the wearable EEG senor measuring connected to database form the major parts of the system. (4) Estimating key concept proficiency system. Virtual reality created by computer and the EEG/ERP technology are combined together.

All above measuring is aimed to support education pedagogy changing with evidence based data, which may record the development pathway of learners and reflect the progress of learners during IBSE activities. Such Systems can be accessed also via internet.

Multiuser On-line Formative Assessment and Record System Used in Teacher’s Training

Theme 1d: Impact of national and international assessments and surveys on IBSE implementation

What has Finland learned from PISA?

Professor Patrik Scheinin, University of Helsinki, Finland

The presentation started with a brief analysis of the Finnish results in the OECD Programme for International Student Assessment (PISA) and what got them here. Implications for Finnish educational policy and influence on science instruction followed.

National and international student assessments in Mexico: balance, challenges and opportunities

Dr. Marlene Gras & Margarita María Zorrilla Fierro, Mexico

The work presented offered both evidence and sustained reflections, but also open ended questions on the topic that could be further explored. Based on what international and national student outcomes show, the country faces critical challenges on inquiry-based education and on assessment itself.

Mexico has an already long history of evaluation of education, dating from the seventies. But it was in the year 2000, coinciding with the democratic transition, that Mexico stepped into a new stage of evaluation. In the last 12 years, Mexico has seen a significant increase of large-scale external evaluations, both national and international. The greatest challenge that the country is facing in this matter appears to be the articulation of all evaluation and assessment actions into one encompassing evaluation and assessment policy framework, along with the communication of evaluation purposes and means to all stakeholders. Lacking of this overarching framework presents challenges and opportunities to the system and to the teaching and learning practices in the classroom that need to be addressed in the short term.

Mexico, a country rich in natural resources, strong traditions, and a wide array of landscapes, climates and food, is a country of contrasts. And this is also true of its people´s living conditions:

- Primary school, ages 6 to 11, has basically universal coverage of 98.3%, but drop-out is still an issue from ages 12 to 14, with a 91.6% coverage. When we look at coverage for ages 15-17, the situation worsens, leaving only 64.8% of those who should be attending school, actually in school.[1]
- In Mexico, living poverty, rural communities or being indigenous also means lower educational outcomes.[2] Equity is a big issue in this multifaceted country. On top of that, social mobility is very low. In other words, it is a country that lacks a vision and practice of meritocracy. [3]

The presentation focused on the evaluations that are implemented on a periodical basis: international (PISA) and national (EXCALE, ENLACE). All three evaluations in all the areas each one covers, show a large portion of the student population not reaching a sufficient level of proficiency or acquired knowledge.

One could say that Mexico suffers a sort of unstructured standardized and large-scale evaluation “rash”, from which we can observe benefits but also downfalls:

- A great amount of data, a lot of it comparable within years; data collected for different purposes, serves a repository of knowledge on the system: Mexico counts

[1] INEE (2011) Panorama Educativo 2010
[2] INEE (2009) El Derecho a la Educación en México
[3] (Fundación ESRU, 2008)Nos Movemos: Movilidad social en México

with data from all PISA editions, Excale has been implemented since 2005 and ENLACE since 2006.

- There should also be enough evidence by now of the unwanted consequences of these test-driven rash. But this has not been a topic of strong discussion in Mexico. Actually, results of these three evaluations are taken as the failure of the system. It is also believed, that by training students to solve PISA-like, Excale-like and ENLACE-like items, they will develop the skills these evaluations attempt to measure.
- A formal study on does not exist, but the authors of this work have observed in several states and schools of varied socio-economic backgrounds a series of unwanted effects of evaluation in school and teaching practices. These practices have a direct impact on IBSE.

SOME CAUSES	SOME UNWANTED CONSEQUENCES
▪ A lack of an overarching evaluation and assessment framework. ▪ Over valued practice of testing opposed to assessing. ▪ A compelling idea that the more testing is applied, more probabilities there are to improve, instead of a serious investment in long-term and most needed reforms that entails undertaking a re-engineering of processes (Eg. Teacher Initial and Continuous Formation) ▪ Poor communication of the uses of different results. ▪ A social construct that evaluation results have to be updated every year to be valid. ▪ Attaching high stakes consequences to ENLACE ▪ A tradition in summative evaluation, emphasized in numerical notes. ▪ A tradition of repetition. ▪ A lack of teacher formation and training in formative evaluation.	▪ Teaching to the test (especially with ENLACE and Pisa) ▪ Teachers and policymakers believing that student outcomes have to be standardized and large-scaled to be valid. ▪ Teachers feeling incapable of assessing their students needs and buying ready made tests for their use in the classroom, thus minimizing time to reflect on each classroom and student´s needs. ▪ Editing houses producing exams that are ENLACE-like. ▪ Misuse: Not using the evaluations for what they are for, using system level evaluations to make judgments on schools, etc. ▪ Great monetary resources not used to their best.

We also observe that Mexico has a clear momentum of opportunity to benefit from:

- Currently undergoing Curriculum Reform: new contents, new methodologies, new settings
- A refreshed discourse on assessment practices world-wide
- A great amount of data collected in the past years
- A large number of new teachers pouring into the work-force every year
- IBSE: active groups in Mexico, both NGOs and Industry

FURTHER QUESTIONS TO ADDRESS

- How can one link large-scale evaluation to better classroom and teacher practices. How to make assessment practices flourish within schools and classrooms, in spite of policy makers focused concern on tests and large-scale comparable data?
- How can a country link policy decision making to evaluations? What organisms do successful countries link in order to make a better use of evaluations?

CONCLUSIONS

Mexico would benefit strongly with the creation of a comprehensive framework of evaluation and assessment, with clear and well-distinguished uses and the respective coherent communication. Also with further studying and acknowledging the unwanted negative effects of large-scale evaluation and misuse of results. These actions would enable a virtuous circle of evaluation, assessment and correct practices, which would not undermine classroom and school practices, but enhance timely decisions at every level of the system. Since this framework and consensus doesn´t exist, great confusion and mis-practices can be observed in all stakeholders.

Theme 1e: Assessment and the curriculum

Effects of Assessment on Implementation of IBSE in the United States

Hubert M. Dyasi, Ph.D.

Two questions need to be answered: Are multiple external, standardized tests currently in use in the United States fairly representative of inquiry-based science education (IBSE)? What have been the consequences of the use of these existing tests in the teaching of IBSE?

State Science Tests

In the US science tests administered by the States are based on the latter's respective science curricula, which are usually derived from State science education standards. The Fordham Institute in Washington, DC recently conducted a comparison of the State Standards with the newly published *Framework of Science Education for K-12 Science Education* [4] (NRC) based on "content and rigor" and on "clarity and specificity". These two parts were combined to yield a score, which was then converted into a letter grade. The Institute's study has concluded:

"A majority of the states' standards remain mediocre to awful. In fact, the average grade across *all* states is — once again — a thoroughly undistinguished C…"

"In twenty-seven jurisdictions, the science standards earn a D or below…"

"…just thirteen jurisdictions — barely 25 percent, and fewer than in 2005 — earn a B or better for setting appropriately clear, rigorous, and specific standards."[5]

In all States, science inquiry and science practices are not well-covered in the tests.

Effects of the tests

According to the *Center on Education Policy,*[6] in cases where science is not subject to high stakes testing, the amount of time allocated to its teaching in the elementary school decreased. When science is part of high stakes testing, science teaching is atomized into discrete, test-related. In addition, research studies have shown that high stakes testing in science also leads to teacher-centered teaching due to teachers' efforts to cover numerous required topics and procedures.[7] This clearly indicates that high stakes testing control the science curriculum.

Nationally, in the National Assessment of Educational Progress (NAEP) tests science inquiry and practices are well-represented.

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[4] National Research Council. A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, D.C.: The National Academies Press 2012.

[5] Lerner, L.S., Goodenough, U., Lynch, J., Schwartz, M., & Schwartz. R. The state of state science standards 2012. Washington, D.C. 20036: Thomas Fordham Institute, January 31, 2012, pp. 5-6.

[6] Center on Education Policy (February 2007). District survey, item 19 (revised tables IT-2A, IT-16, & IT-17, p.7).

[7] Au, Wayne (2007). High-stakes testing and curricular control: A qualitative metasynthesis. *Educational researcher*, Vol. 36, No. 5, pp. 258–267.

Percentage distribution of target and actual assessment time in NAEP science, by science practice and grade: 2009

	Identifying Science Principles		**Using Science Principles**		**Using Scientific Inquiry**		**Using Technological Design**	
	Target	**Actual**	**Target**	**Actual**	**Target**	**Actual**	**Target**	**Actual**
Grade 4	30%	24%	30%	33%	30%	34%	10%	10%
Grade 8	25%	25%	35%	37%	30%	28%	10%	10%
Grade 12	20%	21%	40%	43%	30%	28%	10%	8%

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2009 Science Assessment.

Though not required at State levels, these tests should serve as models for State test development, even in the face of the enormous human and material resources that would be required for such an undertaking.

Assessment of science in France's primary and middle schools

Edith Saltiel, France

The implementation of IBSE, in the decade 2000-2010, in French schools, has been accompanied by efforts to take student assessment into account.

It should be remembered that the IBSE implementation was first the result of an independent action in primary schools by the French Academy of science with Georges Charpak, named *La main à la pâte*, beginning in 1996. The action continues at primary school and middle school in 2012 under the Academy of science leadership and in collaboration with the ministry of education.

Its impact on public education authorities has been profound and the new curricula for science and technology – for primary school (grades 1 to 5) in 2008 and for middle school (grades 5 to 9) in 2009 – prioritize inquiry.

In 2006, there was promulgation, for compulsory education (grades 1 to 9) of the *Common base of knowledge and skills*: it was a great novelty. It deals indeed with knowledge but also with skills, a new concept for French teachers. In 2008 the ministry has published (for the end of primary school) and in 2009 (for the end of middle school) an *Individual booklet on skills*, which is supposed to follow every student, year after year.

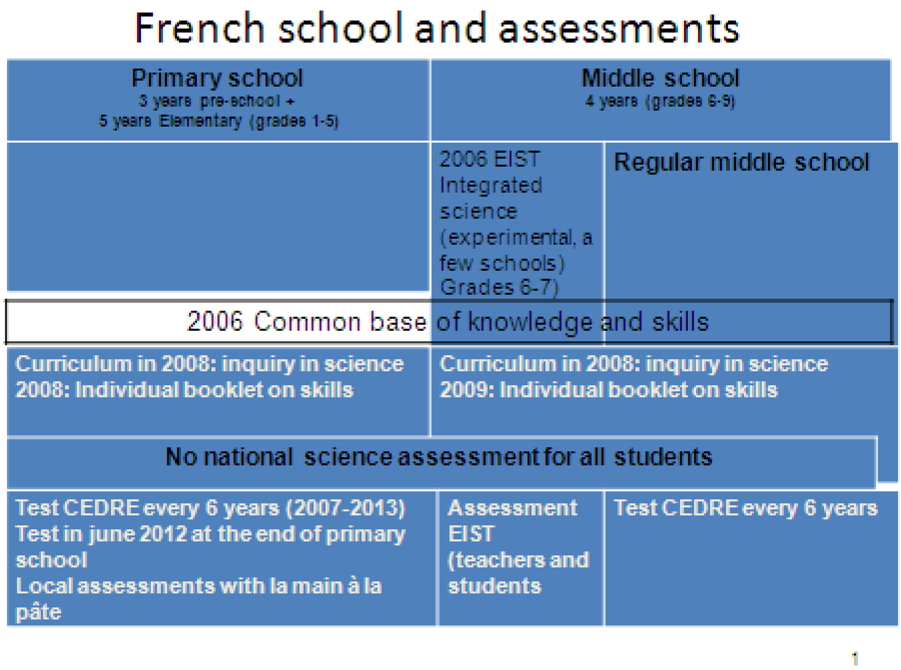
Today, two approaches exist: the national official approach and the more experimental one by *La main à la pâte*.

- The ministry (Direction de l'évaluation, de la prospective et de la performance, DEPP) has organized three kinds of assessment of statistically significant samples of anonymous students.
- A working group of representatives of pilot centers and members of the *La main à la pâte* team developed a table to accurately establish which type of activities will allow a proper assessment of skills. In parallel, local and large scale formative assessments were developed, as in the Perpignan Pilot center, in the Toulouse area Pilot centers and in Strasbourg.

The curriculum and the Common Basis of knowledge and skills have a double goal. First, making sure that all teachers do practice science. Second, making sure that they implement an IBSE pedagogy, where skills acquisition is aimed at. It seems that the ministry has chosen to impulse changes in science education by using assessment. After the Common Basis was promulgated, the ministry has chosen to work on assessment procedures by imposing an Individual Booklet on skills, hoping it would favorably impact science pedagogy and education.

The Common Basis is forcing teachers, teacher trainers and inspectors to think about the methods to assess skills. In collaboration with *La main à la pâte,* the ministry made available on its website some tools to help primary school teachers, but the most significant work has been done locally, in collaboration with the *La main à la pâte* Pilot centers, and shows encouraging results.

Let us make a final and important remark about this survey of current practices in France. It is fine to assess a given student with respect to the IBSE goals, but this assessment has to include some measurement of the quality of the IBSE practice by the teacher himself. This is still far from being always done. This key point weakens some of the conclusions drawn on the basis or the current assessment practices and should be carefully looked at in the future.



Theme 1f: Equality in science education and assessment

Participations of girls in science education in Tunisia

Faouzia Farida Charfi, Professor of Physics, University of Tunis

Education and emancipation of women were the two priorities for the construction of a modern state after the independence of Tunisia in 1956. Coder of Personal Status was decreed on August 13th, 1956, a choice shared by Tunisian elite impregnated with ideas of Islamic thinkers like Tahar Haddad. This great theologian wrote in 1930, *Our women, legislation and society* ; he recognized a woman's right to unveil herself and to go to work, basing his conception on an audacious interpretation of Koranic verses: "*Duty calls us today more than ever to remove women from the obscurantism of centuries past and to consider them as living members and an equal partner in our lives ..I see them advancing on the path of knowledge and education, making the necessary sacrifices, that is the price of our salvation and our freedom".*

The important efforts for the education sector in Tunisia, particularly the results of mandatory education since the education law of 1991 and the success of the policy in favour of gender equality lead to the current situation of education: about two millions pupils (on a population of 10 millions people) are enrolled in the two cycles of public education, 50.5% of which are girls. A little more girl (58%) is enrolled in the secondary schools. Girls have better performance due to the fact that success in their study could give them freedom to leave their parental home, then to access to financial freedom by getting a job. The rates of girls in the different sections, last year of secondary school show that i) the sections with more girls are: Literature (76%), a field traditionally preferred by the girls; experimental section (73%), leading to biological and medical studies, and also mathematics (53.0 %), the more selective one ii) girls represent only 26% in the technical science. Girls represent the majority of students in university (63%). However 2/3 of the unemployed graduates are women due probably to the great number of girls in literature section and preference of the private sector to employ men.

In conclusion, it would be important to consolidate the achievements and benefits from the progress of girls in the school system and find a better adequacy University-Enterprise as well to improve science teaching at all levels of education, particularly in the basic school. Science is introduced as a course called « scientific awareness ». The conception of these courses has to be more experimental and « *La main à la pâte* » could be an important improvement for the scientific development of the young people in Tunisia. Valuable policies of sustainable development, a new vision of environment, more research on energy, have to be engaged. To reach these goals, adequate scientific skills development and collaboration with other countries are necessary for the future of the country.

Patterns of gender similarity and difference in science: implications for IBSE instruction and assessment?

Sandra Johnson, Assessment Europe (France)

The aims of the presentation were:

1. to overview some principal similarities and differences between the science performances, attitudes and interests of boys and girls, as revealed in large-scale surveys
2. to consider possible teaching and assessment implications.

Science knowledge and understanding

TIMSS surveys in the primary school and lower secondary school have revealed an inconsistent picture as far as gender difference in science knowledge and understanding is concerned (Mullis et al. 2008; Royal Society 2010). Gender gaps in achievement have appeared in some but not all countries, and these have varied in direction (relatively low numbers of items, item theming, and a pretesting strategy that specifically aims to eliminate subgroup differences could explain this pattern to an extent). Some national surveys, on the other hand, have provided evidence of a consistent and strong gender difference in favour of boys in physical science (e.g. SG 2008), as have the OECD's PISA surveys of 15-year-olds (PISA 2009).

Practically-based investigation skills

For cost and logistic reasons, practically-based science investigation skills are rarely assessed in large-scale surveys. Where they have been assessed no gender differences have been noted: see, for example, Gilmore, Lovett and van Hasselt (2003) for results from New Zealand's National Education Monitoring Programme (NEMP) and SEED (2005) for Scotland's Assessment of Achievement Programme (AAP). It is worth noting that by their nature biological science investigations fit less comfortably than physical science investigations into the timed testing context of large-scale assessment exercises and so feature less prominently.

Attitudes and interests

Enthusiasm for both mathematics and science learning decreases as pupils move through their schooling (e.g. Gilmore et al. 2003 for New Zealand. SG 2008 for Scotland; Mullis et al. 2008 for TIMSS). This is despite a general perception on the part of pupils that both subjects are important for later learning and employment. Interestingly, in Scotland at least (SG 2008), while both genders appreciate the utility of science and mathematics, boys tend more than girls to consider science to be 'useful for jobs'. Within 'science', topic interests differ between boys and girls, with girls from a relatively early age preferring biological and environmental science and boys physical science (SG 2008). This divergence in interest strengthens with age. Boys enjoy practically-based activities more than girls, and express greater confidence than girls in learning and, in particular, in 'doing' science, especially in the secondary school; boys also tend to be more positive in their self assessments of ability and achievement (Gilmore et al. 2003; SG 2008).

Implications for IBSE instruction and assessment?

If there is an issue to do with the science learning and achievement of boys and girls, and their later study and career choices, then it must surely focus on physical science in obligatory schooling. Is action needed to change the current situation? If so, what form might this take? These are key questions. Do we put effort into improving the knowledge and understanding of the physical sciences among intending primary school teachers, the majority of whom are women who by default serve as early role models for girls? Do we build on the gender-typed interests of boys and girls by introducing topic differentiation into the classroom (if that can be achieved in practice), reinforcing the current gender gap in interests and career aspirations, rather than continuing with a common curriculum for all? If IBSE is given a greater role in the classroom, what would be the appropriate mix of practically-based versus internet-based investigative activity, given the gender gap in interest and confidence when manipulating equipment? Finally, to what extent could/should modes of assessment match modes of instruction?

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Theme 2: The relationship between science education and industry

Corporate Social Responsibility – A Win-Win for both business and educators

S. Anders Hedberg, Ph. D., Hedberg Consulting, LLC.

The economic developments of recent years have affected us all. National economies always fluctuate but because of the close interconnectedness of countries, organizations and people – the Global Economy – changes now impact us more directly and more quickly than ever before. However, a positive consequence of recent national economic crises is the healthy discussion about how to prevent similar problems in the future through better education and more strategic workforce preparation.

Predominantly, the global economy is driven by trade, and corporations have adjusted their operations to capitalize on access to new markets, adapting quickly to changing business environments and even driving change. This also includes how they seek, recruit and retain talent.

At a time when science, technology, engineering and mathematics (STEM) education must be strengthened, it is more important than ever that we understand the changing workplace environment and make use of that knowledge to better prepare tomorrow's workforce.

How is the evolving global economy driving change in the workplace?

Domestic corporations and multinational enterprises (MNEs) often work in formal partnerships and strategic alliances across organizational boundaries and national borders. This means that their goals, operational principles, standards of quality, ethics and conduct are constantly influenced by other members of their networks. As business norms change, every member becomes aware and adjusts accordingly. This means that change happens quickly, and at some level change is continuously ongoing (Albrecht and Sack, 2000).

Studies of the impact of company size on productivity and growth gave rise to descriptors borrowed from the animal kingdom. Birch and Medoff (1994) labeled small (less than 20 employees) and large companies (more than 500 employees) as Mice and Elephants, respectively. Neither of these two "species" generate significant new employment. Enterprises who grow quickly by acquiring their competitors may approach a plateau of productivity (Dickerson et al, 1997) and may find themselves in competition with Gazelles (Birch and Medoff, 1994). These are neither small nor large, but often young, nimble and fast moving companies, quick to adapt to change (Acs and Mueller, 2008). Innovation boutique businesses with few employees and even fewer, highly specialized products designed for niche markets, are sometimes destined to become acquired by an elephant. Today, symbiotic relationships between all three species can be found as strategic alliances and interactions that drive business evolution and promote innovation (Gabrielsson et al, 2011; Spilling and Stensli, 2004).

Operational adaptations have led to new demands on the individual employees: The very large departments growing inside the elephant corporations, characterized by many layers of management, have been found to foster risk aversion, inertia and slow decision-making.

"Flattening" of organizational units have led to increased personal accountability, faster communication and quicker decision making made deep down in the organization (Hammer and Champy, 2003; Industry Week, 1998; Malone, 2004). Many businesses encourage employees to become "intrapreneurs" who engage their skill portfolio where it is best needed within the business, and who are sought out by task teams in need of a specialist (Carrier, 2009; Filion, 2002; Wunderer, 2001).

These new business behaviors reward employees who are innovative, creative and good team contributors, leading to opportunities for personal and professional development, self-reliance and accountability (Bassi and McMurrer, 2008; Industry Week 1998). These experiences have taught the workplace sector the importance and value of having skilled employees at the right place at the right time (Guthridge 2008; Rawlinson et al, 2008; Siegel, 2008).

This represents only a tiny fraction of the changes that permeate today's science business sector. Yet, armed with knowledge about these trends educators would be able to help prepare students for the realities of the workplace while they are still in the classroom, helping them secure employment and develop strong careers.

Add to that the generic workplace skills that are largely independent of the business specialization, but nonetheless necessary for success in the workplace. These include the following roster, promoted by the Partnership for 21st Century Skills (p21) and included in some states' standards for 21st Century Life and Career Skills (New Jersey Dept. of Education 2009):

- Critical thinking and problem solving
- Creativity and innovation
- Collaboration, team work and leadership
- Cross-cultural understanding and interpersonal communication
- Communication and media fluency
- Accountability, productivity and ethics

It is important to recognize that these skills and behaviors are by no means isolated to the leadership layers of business. Neither are they unique to the STEM-based workplace. All areas of a modern workplace, from maintenance and manufacturing to product design, marketing and strategic planning rely on technically savvy workers, who can recognize problems, find facts and use them appropriately to design solutions.

Is the global economy also driving change in education?

The evolution of our current global systems of communication and trade largely coincides with the shift of generations and change from one millennium to the next. As generation shifts go, none are painless and none are instant. Children born into the 21st century are now taught – and will be for another ten years or so, by teachers who themselves were educated and trained during the last century. What is the significance of that?

When considering the rapidly evolving global economy, scientific and technological advancements and communication, those of us born, educated and trained in the latter half of the twentieth century might not be terribly well suited to prepare the next generation for life and realities of tomorrow's communities. Many of us have had to learn new skills, change ingrained behaviors, reset old values, and by and large hang on for dear life just to make a living, embedded in new social norms, depending on new technologies and sometimes even competing with our children for jobs.

Surely, it might be easier for students to relate to 21st century contemporary teachers who have grown up in social networks and who are fully comfortable with digitally enhanced life.

However, we – the Baby Boomers and "Generation X'ers"8, have yet to build our own legacy for the new millennium. This will be the development of a new visionary and effective partnership between business and education to secure the future of our next generation and our shared global economy. We are well suited to do this because we have seen the results of failure in this area. And we have an obligation to share this empirical knowledge with tomorrow's leaders who doubtlessly will experience unfathomable advances in technology and science and may have to shoulder an even greater responsibility to advance education through new innovation.

Education, as one of the essential drivers of community stability and development, stands to gain considerably from a close relationship with the workplace sector. By viewing the workplace sector as its primary customer, who acquires and uses the product of education – prepared talent, educators are better able to design this product to meet the customer's needs.

Why are we in this dilemma?

As a society, we are by nature resistant to change. The two sectors we are concerned with in this case, the education sector and the workplace sector have both done their jobs, however in splendid isolation from one another. This was adequate as long as schools put out workforce-ready graduates who were able to meet the prevailing expectations. Up through the mid-1900's, this was largely the case. But we failed to react when the rate of technological development began to exceed the capacity for curriculum developers to keep up. Ever since, the divergence has increased as the rate of change in the workplace sector accelerates while change is remains slow in education.

This situation is not the fault of the educators who are at the mercy of elected officials and periodically changing, politically motivated education policies. Further, they are struggling with budgetary constraints, demanding social policies, dropping interest levels among students, and lack of broad support from the general public. For what they are asked to do, they have largely met their own performance standards under difficult circumstances.

The corporate sector can also not be blamed for a lack of effective education partnerships. First, because businesses do what they are good at, namely minding their business (just like the educators). Second, because very few incentives are being offered for engaging in education. Only a handful of nations grant tax advantage for charitable giving, but where this is the case, non-profit advocacy is commonly supported by the private sector.

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[8] US Population Reference Bureau: Baby Boomers: Born 1946-1964; Generation X: 1965-1982; GenerationY/Millennial Generation: 1983-2001.

Here is where the strategic opportunity lies. When corporations devise charitable giving programs, they rely of philanthropy professionals to design and execute their missions, working either from within separate corporate foundations, or as staff in the departments of corporate philanthropy. These professionals operate in the interface between the business world and the communities where workplaces reside and are therefore perfect liaisons and mission leaders for our cause. They are particularly well suited to translate education needs into business language and help develop convincing arguments for corporate support.

What Can and Must Be Done?

In order to secure the future of our children's generation we must understand how to better prepare tomorrow's workforce. This can best be achieved by establishing an open and productive dialog between the producer and customer in the talent market place. There is much time lost to failed communication to make up for, and it is extremely urgent to ensure that educators become informed of the new knowledge and skills required for employment and success in the workplace. Business must also assume responsibility for sharing their projection for future talent needs with educators.

Corporate Social Responsibility (CSR) is rapidly becoming a globally recognized element in strategic business planning. Doing good by doing well makes good business sense, viewed from several angles. Since the Millenium Generation has a strong affinity for socially conscious organizations (Winograd & Hais, 2008), carefully designed CSR can help attract discerning workers. Customers and share holders alike value corporations that play an active role in the communities where they live and work and give back some of their profit and expertise to society. Further, truly altruistic corporate leaders are often respected by both their peers and the general public.

By establishing a close relationship with educators business makes a smart investment in its supply chain. The acquisition of well-prepared talent is both expensive and time consuming. Productive business-education partnerships simply make good business sense for both partners since they reduce cost of product refinement (less expensive on-the-job training and remedial education will be needed) and waste (more students will find jobs, saving the community considerable unemployment costs).

As we have discussed earlier in this paper, the workplace dynamics will lead to ever-changing needs for new talent (Schuler et al, 2011; Tarique and Schuler, 2010). Consequently, the exchange between the education and workplace sectors can never stop. We are constantly aiming at a moving target. There will always be a "Tomorrow's Workforce" sitting in a classroom and those students must be given the benefit of understanding new trends in the workplace. By building the dialog on a program platform based on exchange between workplaces and schools, a dynamic, uninterrupted communication can be sustained. Such program models have been developed and found useful in opening doors between schools and the workplace (Hedberg, 2012).

This argument is not one tied to any particular national agenda of economic dominance, but rather to one of global citizenship.

Developing global citizens and a strong global talent pool.

We can expect that over the next several years, students who are now in school will be far more comfortable as global citizens than we are today. Many of them will seek jobs in countries far away from where they grew up, and contribute to their new home country's economy but also to the global economy. However, many will not want to leave their native country at all, others will return after some time abroad, and populations of foreign students will immigrate. Thus, any fear that these efforts will contribute to the success of other nations' talent pool at the expense of our own, is likely to be unfounded.

It is widely recognized by competitive corporate recruiters, but not by schools, that their corporate culture and values are as powerful in helping to attract talent as the financial compensation. The future talent market may therefore benefit more from national policies designed to welcome visionary foreign business investment with an expectation that CSR be part of their commitment to their new host countries. Isolationist economic policies, on the other hand are not likely to help retain talent.

When established in a new country companies quickly develop relationships with governments and communities who see their presence as an asset. They now have opportunities to bring innovative ideas and programs to their new host country. CSR can now be as effective a tool for strengthening their new communities and helping to prepare the local workforce as back home in the native countries, providing resources and engaging volunteers in the improvement of education. Their own local employees will obviously also be among the beneficiaries.

Education programs that build on a close working relationship between business, government and schools can have particular impact in building productive relationships between corporations and their host communities, since positive experiences can quickly lead to replication by other businesses giving rise to corporate collaboration and synergistic outcomes.

Long-range planning and sustainability

A particularly valuable result from these public-private partnerships is the increased mutual understanding of professional cultures and values that characterize the business and education environments, respectively. Both parties will benefit from comprehending what challenges their partner faces, and how they anticipate, meet and overcome them. Through the process of team building, they will come to share a vision for their joint effort, increase their capacity and build a plan for sustainability based on new leadership development and partnership expansion.

While collaborative work must begin immediately to address the issues raised earlier in this paper, it will be wise to plan for a long-range effort. Education as a field of research is notoriously difficult due to the many factors that conspire to sabotage controlled studies: Mobility of teachers and students, lack of standardized pedagogical practices, resource deficiency, changing leadership, etc. Measurement of Outcomes of programmatic initiatives are even less reliable. However, effective programs survive and grow on their own merits, even if summative evaluations might yield convincing data several years downstream.

The following key objectives should be considered in developing a STEM workforce development agenda based on business-education partnership:

- Encourage legislators and top education leaders to define education goals that include workforce preparation informed by public-private partnerships.
- Build corporate involvement on a CSR mission that supports communities where employees live and work.
- Develop a Corporate Value Proposition based on need for and access to prepared STEM talent.
- Develop an Education Value Proposition based on need for access to information about workforce knowledge and skills, now and in the future.
- Explore and encourage opportunities for MNEs to "import" CSR programs with focus on education.
- Encourage elected officials and community leaders to reward CSR programs that benefit the talent market and therefore economic prosperity and growth.

If executed deliberately, with compassion for students and mindfulness of all stakeholders' interests, such initiatives yield benefits to all involved and deserve the label "Win-Win" Solutions.

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Theme 2a: Science education & socio-economic challenges

Expectations towards science education rise and change

Mrs. Marita Aho, senior adviser, Confederation of Finnish Industries EK

Competition between companies: things must be done with the goal of creating something new. The skill and education needs of a innovation-driven society were studied in the foresight project "Oivallus" , a three-year project co-ordinated by EK in 2008-2011.

The competitive edge of a company can be based on three things. The first alternative is making things at a lower price than others. The second option is making things at the same price as others, but better. The third alternative is innovation-based competition: doing something that nobody else is doing or cannot do.

In order to be innovative, companies are changing their ways of operating. Work is done more in projects, with varying combinations of skills. Specific instructions are replaced with guidelines. People themselves need to define the content and the rules of work. This kind of work needs other skills than the "old" work! Is our current education system based on the needs of the modern working life? Does science education automatically enhance innovations? How could it do better?

The relationship between science education and industry

Ana Costa Freitas, Adviser, Chief Scientific Adviser Office
Bureau of European Policy Advisers, European Commission

Why do we need Science Education?

1. Our main competitors abroad are investing in higher education and putting many more of their young people through university!
2. While 35% of all jobs in the European Union will require high-level qualifications by 2020, only 26% of the workforce currently has a higher education qualification.
3. 1 in 5 young European cannot find work now!

Commission proposals for a Smart Sustainable inclusive Growth: wish to achieve by 2020:

1. Reduce early school leaving to 10% from the current 15%;
2. Increase the share of young Europeans having successfully completed higher education from 31% to at least 40%.

However a study of Eurobarometer on “Europeans, Science and Technology” reports that only 15% of Europeans are satisfied with the quality of science classes in school.
We have to do it better:

1. Educational **QUALITY**, rather than mere school attainment, is strongly related to the distribution of income and to the economic growth.
2. Promoting excellence in higher education includes:
    a. improving the relevance of **programmes to labour market needs**,
    b. rewarding **excellent teaching**,
    c. increasing **flexibility in programmes**,
    d. encouraging **mobility and facilitating the cross-border** dissemination of ideas and best practices.

We have to ensure Europe is **training and retaining** sufficient numbers of high level scientists and engineers needed for its **future economic and technological development**.

a. Availability of highly qualified science and technology professionals is a key factor for the establishment, import and success of **high-tech industry** in the European Union.
b. Europe should be in a position to anticipate, rather than follow demand, as it moves towards a **“knowledge based economy”.**

Industry, as a main Stakeholder, plays an important role in helping bridging the gap between the worlds of education and work.

Contribution of basic research in the academia to industry and economic development

Ruth Arnon, The Weizmann Institute of Science and
President of The Israel Academy of Sciences

Education is the responsibility of universities, but in addition they are also responsible for scientific research. The research in academic institutions is mostly basic, namely curiosity-driven. However, in some cases it results in innovations and reaches a stage when these are applicable. Technology Transfer leads to conversion of the applicable to applied research and development. Development into a product is possible only in industry. It should be borne in mind that only a fraction of basic research leads to applicable innovations and only a small fraction of those become applied, but they provide a significant contribution. In the following are several examples from Israeli research.

I. Mathematics and Computer Science

1) LZ (Lampel-Ziv) algorithm (Technion) for data compression and transmission. Its application leads to softwares including ZIP, TIFF, JPG etc…, which enable the transmission of pictures, also to space and back.
2) RSA (Rivest-Shamir-Adelman) algorithm (MIT and Weizmann Institute), dealing with cryptography and the footsteps of the research of Michael Rabin (Hebrew University). Its applications: data management in banking.
3) Flash memory device (Tel Aviv University): application – Disk-on-Key by the company M-System which was recently acquired by Sun Disk for $ 1.5 billion.

II. Chemistry:

1) Discovery of Ubiquitin by Hershko and Ciechanover (Nobel Laureates 2004, Technion).
Application: development of novel anti-cancer drugs.
2) Ribosome structure by Ada Yonath (Nobel Laureate 2009, Weizmann Institute).
Application: potential development of novel antibiotics, based on crystallography.
3) Discovery of Quazicrystals (Nobel Laureate Dan Shechtman, Technion) - novel materials.

III. Nanotechnology:

In the last five years, a tremendous effort was made to develop nanotechnology in all the universities in Israel, leading to many applications, including nanospheres for lubricants, nanotubes as biosensors, DNA fibers as electrical conductors and development of solar cells.

IV. Agriculture:

1) Development of improved wheat strains with high yield
2) Development of Cherry Tomatoes
3) Herbicide- resistant transgenic plants, applied particularly for maize.

V. Biotechnology and Biomedicine:

Several companies based on research and technology initiated in the Israeli universities led to the development of several ethical drugs e.g. Copaxone, Rebif, Excelon, Doxil and Azilect. Other inventions place Israel very high in the development of medical equipment.

In conclusion, in ISRAEL basic research in universities and other academic institutions is often "translated" to applied science. All universities in Israel have Technology Transfer units that secure their Intellectual Property. Technology transfer enables inter-relations with industry (Technological Incubators, as well as Start-up Companies). This interaction promotes the economy.

Mexican experiences in linking business and industry with IBSE programs

Dr Guillermo Fernández de la Garza

The Mexican Industrial sector has now much greater interest than 10 years ago in what can be done to improve basic education, in particular in relation to thinking skills, scientific attitudes and continuing learning capabilities. This is so because of its awareness of the enormous impact of skills, attitudes and capabilities in the innovation and productivity of companies, that are basic to their survival and growth.

INNOVEC, Innovation in Science Education, the Mexican non-profit promoting IBSE programs in basic education, has brought together a group of distinguished business leaders who have analyzed in depth the importance of this type of education to business. It has organized a series of activities over the last 10 years to make business leaders more interested in promoting IBSE programs. In these INNOVEC activities there have been an important participation of business leaders and specialist of other countries. It is clear that the international cooperation linking business leaders involved in promoting IBSE programs, could result in networks that facilitate the flow of information and the sharing of effective experiences to influence the media, the business organizations and governments leading to deeper understanding of the importance of IBSE type programs for innovation and competitiveness.

Theme 2b: Science education & industry: towards new partnerships

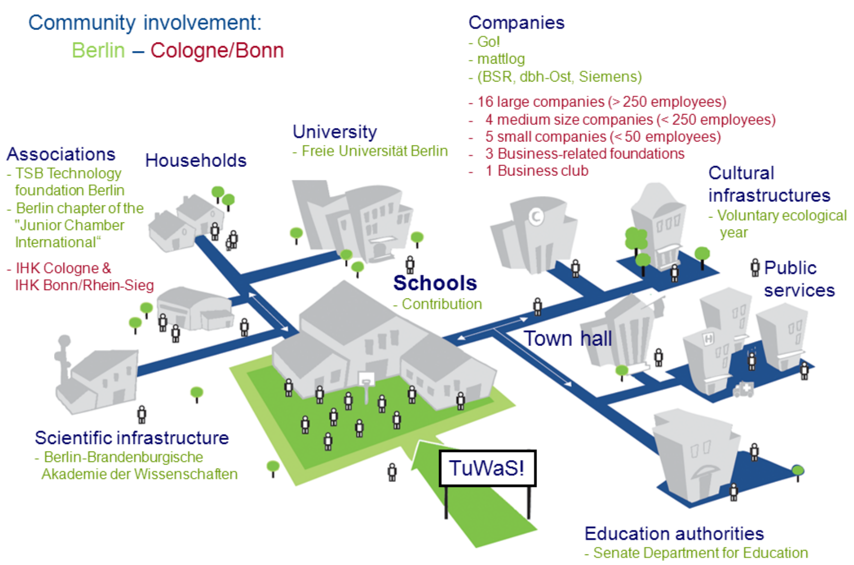
Different models in which industry (& others) supports the inquiry-based science education program TuWaS! in Germany

Petra Skiebe-Corrette, Freie Universtät Berlin , Germany

Anne-Gret Iturriaga Abarzua, Communications Manager, INEOS Köln GmbH, Germany

Supporting education programs should be foremost the responsibility of local or national governments. In Germany, it has been shown in a number of cases that industry, industrial associations or industrial foundations can play a key role in initiating and sustaining a change in education. Based on the example of TuWaS! (Technik und Naturwissenschaften an Schulen, Technology and Science in schools), an IBSE reform program, different strategies are explored in how industry and science education become partners.

TuWaS! is present in four of the 16 German states and was founded in Berlin by the Freie Universität Berlin and the Berlin-Brandenburg Academy of Sciences and Humanities. From its start, TuWaS! was supported by the TSB Technology Foundation Berlin, funding teaching material for technology topics, providing the salary for the head of the material centre and promoting TuWaS! in the community. The second strong supporter is the Senate Department of Education, Youth and Science, which funded the purchase and refurbishment of teaching materials and allowed teachers to work part time for TuWaS! Some companies supply their services, e.g. Go! EXPRESS & LOGISTICS delivers the material to schools and picks them up for refurbishment free of charge. The Berlin chapter of the Junior Chamber International provides professional development. In addition, young volunteers work for a year to help refurbishing the material and organise public events.



The funding sources of TuWaS! in Berlin (green) and in Cologne and Bonn (red), based on a figure developed within the Pollen project funded by the European Union. Pictures from TuWaS! class rooms.

In North Rhine-Westphalia, the Chambers of Industry and Commerce in Cologne and Bonn Rhein-Sieg consulted their members whether to start a project to promote science education in primary schools. After their positive vote, the TuWaS! project was chosen. The Chambers provided seed money and asked member companies for financial support of particular schools. The seed money funded the transfer of knowledge from Berlin to North Rhine-Westphalia, the co-ordination of the program and the initial professional development workshops as well as the teaching materials.

Through fundraising activities, numerous companies, business-related foundations and business clubs were convinced to adopt schools – including 16 large companies, with the chemical company INEOS in Cologne as the largest funder, four middle size companies, five small companies, three business-related foundations and a business club. Effective lobbying is all about taking into account the specifics of a particular company or organisation, aligning the right people and taking care of them.

Appendix A – Conference programme

Wednesday 30 May

9.00 - 9.55 9.55 - 10.15	**Opening of the Conference** Mrs. Armi Mikkola, Ministry of Education, Finland **"Scientists and Education",** Prof. Olli Martio, General Secretary, Finnish Academy of Science and Letters **Opening speech: "Our role in inventing the future"** Prof. Anne Glover, Chief Scientific Advisor to the President of the European Commission, Brussels **Welcome: "IAP Global science education program"** Prof. Pierre Léna, Académie des sciences, France **Keynote speech: " Inquiry Based Education for all"** Prof . Dato Lee Yee Cheong, UNESCO, ISTIC, Akademi Sains, *M*alaysia	Prof Odile Macchi (France)
10.15– 10.45	**Introduction to Theme 1: Student assessment and IBSE** Prof. Wynne Harlen (UK): "**Roles of student assessment in education"** *Discussion*	Prof Pat Rowell (Canada)
10.45 – 11.15	*Coffee break*	
11.15 – 12.45	**Theme 1a: Formative assessment and its relationship with summative assessment** Prof Paul Black (UK): **"Formative and summative – discord or harmony, and why it matters"** Ms. Janet Looney (European Institute of Education and Social Policy): **"Integrating Formative and Summative Assessment: Progress toward a Seamless System?"** *Discussion*	Prof Pat Rowell (Canada)
12.45 – 14.00	*Lunch break*	
14.00 – 15.30	**Theme 1b: Approaches to summative assessment of IBSE** Prof. Jens Dolin (Denmark): **"Different test paradigms – different test results"** Dr Christine Harrison (UK): "**Process Skills or Cognitive Endeavour? What makes a valid assessment of inquiry science?"** *Discussion*	Prof Derek Bell (UK)
15.30 -15.45	*Break*	
15.45 – 16.45	**Theme 1c: Current initiatives in IBSE students**	

	assessment Prof. Dr. Manzoor H. Soomro (Pakistan): **"IBSE in Pakistan- Issues in implementation and students assessment".** Prof. Wei Yu (China) : **"Using Scientific Tools for Formative Assessment and Development of On-line Assessment"** Prof Norma Nudelman (Argentina): **"IBSE Developments in Latin America"** Prof Eliezer Manguelle Dicoum (Cameroon) **"Developing IBSE in Cameroon schools"** Prof. Benő Csapo (Hungary): **"Technology Based Assessment of Science in the First Six Grades"**	Mrs Jackie Olang (Kenya / NASAC)
16:45 – 17:45	**Poster session**	
17:45 – 18:30	Informal and/or group discussions. **End of the day.**	
	Working dinner for the Global Council, IAP Science Education Programme	

Thursday 31 May

9.00 -10.45	**Theme 1d: Impact of national and international assessments and surveys on IBSE implementation** Prof Patrik Scheinin (Finland) : **"What has Finland learned from PISA?"** Dr Marlene Gras and Margarita Marias Zorilla Fierro (Mexico): **"National and international student assessments in Mexico: balance, challenges and opportunities."** *Discussion*	Prof Norma Nudelman (Argentina / IANAS)
10.45 – 11.15	Break	
11.15 – 12.45	**Theme 1e: Assessment and the curriculum** Dr Hubert Dyasi (CUNY, US): "**Effects of Assessment on Implementation of IBSE in the United States"** Prof Edith Saltiel (*La main à la pâte,* France): "**Assessment of science in France's primary and middle schools"** *Discussion*	Prof Wynne Harlen (UK)
12.45 – 14.00	Lunch break	
14.00 – 15.30	**Theme 1f: Equality in science education and assessment** Dr Faouzia Farida Charfi (Tunisia): **"The participation of girls in science education"** Mrs Sandra Johnson (Assessment Europe, France): **"Patterns of gender difference in science:**	Prof Wei Yu (China)

	implications for IBSE instruction and assessment" *Discussion*	
15.30 -15.45	Break	
15.45 – 17.30	**Reports by theme chairs** *Group discussion of theme reports* **General conclusions about student assessment** led by Prof Wynne Harlen	Prof Pierre Léna (France)
	Conference dinner	

Friday 1 June

9.00 - 9.15	**Introduction to Theme 2**: **The relationship between science education and industry**	Dr Rüdiger Klein (NL/ALLEA)
9.15 -10.45	**Theme 2a: Science education & socio-economic challenges** Ms Marita Aho (Confederation of Finnish Industries): **"Expectations towards science education rise and change"** Dr Ana-Maria Costa Freitas (EU President: Bureau of European Policy Advisors), **"Science education - an engine for growth and jobs"** Alexa Joyce (InGenious project manager): **"European Coordinating Body for MST education: the InGenious-project as an example for dialogue platforms with industry".** Dr Guillermo Fernandez de la Garza (Mexico**): Mexican experiences in linking business and industry with IBSE programs** Prof Ruth Arnon (Israel): **Contribution of basic research in the academia to industry and economic development** *Discussion*	Prof Maija Aksela (Finland)
10.45 – 11.15	Break	
11.15 – 12.00	**Theme 2b: Science education & industry: towards new partnerships** Dr. Anders Hedberg (Hedberg Consulting, US): **Corporate Social responsibility: a Win-Win for Education and**	Prof Maija Aksela

	Business Petra Skiebe-Corrette (Free University Berlin, Germany) and Dr. Anne-Gret Abarzua (INEOS): **Different models in which industry (& others) support the inquiry-based science education program TuWaS! in Germany** *Discussion*	(Finland)
12.00 – 12.45	**Panel discussion** (Speakers and Chairs of Theme 2) *Discussion of follow-up activities*	Prof Peter Mitchell(Ireland)
12.45 – 13.00	**Conference closure**	Prof Pierre Léna
13.00 – 14.00	Lunch break	
13:30 – 16:30 **14.00 – 15.30**	**Parallel meetings of IAP Regional Councils of the Science Education Programme (SEP)** - ALLEA WG Science Education-IAP SEP Europe Council - Africa (NASAC) SEP Council - Americas (IANAS) SEP Council - Asia-Pacific (FASAS) SEP Council	Prof Odile Macchi Mrs Jackie Olang Pr. Norma Nudelman Prof Jenny Graves

Appendix B – Participants Contact Details

IAP COUNCIL MEMBERS			
Bell, Derek	UK	derek@campanulaconsulting.co.uk	Professor of Education in The College of Teachers, Visiting Research Associate, Institute of Education, London.
Dyasi, Hubert	USA	Hdyasi@aol.com	
Fernandez de la Garza, Guillermo	Mexico	gfernandez@fumec.org	Fundación México-estados Unidos par la Ciencia (FUMEC)
Graves, Jenny	Australia	jenny.graves@anu.edu.au	Secretary for Education and Public Affairs, The Australian Academy of Science
Harlen, Wynne	UK	wynne@torphin.freeserve.co.uk	Visiting Professor at the University of Bristol, Editor of Primary Science Review
Léna, Pierre	France	pierre.lena@obspm.fr	Académie des sciences, France
Macchi, Odile	France	macchi.odile@orange.fr	Académie des sciences, France
Olang, Jackie	Kenya	j.olang@aasciences.org	NASAC, Nairobi, Kenya
Rowell, Patricia	Canada	prowell@ualberta.ca	University of Alberta, Edmonton, Canada
Sbarbati Nudelman, Norma	Argentina	nudelman@qo.fcen.uba.ar	Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina
Wei, Yu	Chine	ywrcls@yahoo.com.cn	Research Center for Learning Science, Southeast University, Nanjing China
SPEAKERS			
Aho, Marita	Finland	marita.aho@ek.fi	Confederation of Finnish Industries EK
Charfi, Faouzia Farida	Tunisia	faouziacharfi@hotmail.fr	University of TUNIS
Black, Paul	UK	paul.black@kcl.ac.uk	King's College London
Costa Freitas, Ana-Maria	EU		
Dolin, Jens	Denmark	dolin@ind.ku.dk	King's College, London
Gras, Marlene	Mexico	gras.marlene@gmail.com	
Harrison, Chris	UK	Christine.harrison@kcl.ac.uk	
Hedberg, Anders	USA	anders@hedbergconsultingllc.com	Hedberg Consulting, LLC, Pennsylvania, US
Iturriaga Abarzua, Anne-Gret	Germany	anne-gret.iturriaga.abarzua@ineos.com	Communications Manager, INEOS Köln GmbH
Johnson, Sandra	France	Sandra.Johnson@Assessment-Europe.com	Assessment Europe, France
Joyce, Alexa *(web-link presentation)*	EUN		
Yee-Chong, Dato' Lee	Malaysia	dlyeec@unifi.my	Chairman UNESCO International Science Technology and Innovation Centre for S-S Cooperation
Looney, Janet		janetlooney1@yahoo.fr	

Mikkola, Armi	Finland	armi.mikkola@minedu.fi	Ministry of Education and Culture
Saltiel, Edith	France	edith.saltiel@fondation-lamap.org	Fondation La main à la pâte
Scheinin, Patrick	Finland	patrik.scheinin@helsinki.fi	
Skiebe-Corrette, Petra	Germany	skiebe@zedat.fu-berlin.de	Freie Universität Berlin, Department of Biology, Chemistry, Pharmacy
IAP NETWORKS / AFRICA NASAC			
Gadzekpo, V. P. Y.	Ghana	vgadzekpo@yahoo.com	Central Uty College, Miotso, Tema
Hapanyengwi, Gilford T	Zimbabwe	ghapanyengwi@compcentre.uz.ac.zw.	Secretary General of the Zimbabwe Academy of Sciences
Luhanga, Matthew L.	Tanzania	mluhanga@udsm.ac.tz	President of the Tanzania Academy of Sciences
Sabiiti, Elly	Uganda	esabiiti@agric.mak.ac.ug sabiiti@gmail.com	TWAS Research Professor, Vice President, School of Agricultural Sciences, Makerere University, Kampala, Uganda
Grayson, Diane	South Africa	dgrayson@absamail.co.za	University of Pretoria & Academy of science of South Africa
Lewanika, Mwananyanda Mbikusita	Zambia	mwananyanda_lewanika@stemz.co.zm	Zambia Academy of Sciences
Manguelle-Dicoum, Eliezer	Cameroon	madicoum@yahoo.fr	Cameroon Academy of sciences
Maudarbocus, Yousuf	Mauritius	mbmltd@intnet.mu	Mauritius Academy of Science & Technology
Mavanga, Gil Gabriel	Mozambique	ggmavanga@gmail.com	Mozambican Academy of Science
Wague, Ahmadou	Senegal	wague@refer.sn	Academie Nationale des Sciences et Techniques du Senegal (ANSTS)
IAP NETWORKS / AMERICAS IANAS			
Hernandez, Diana	Venezuela	dmhernandezs@gmail.com	Ciencia en la Escuela Academia de Ciencias Fisicas Matematicas y Naturales de Venezuela (supported by Fundación Empresas Polar)
Lozano, José A.	Colombia	jlozano@accefyn.org.co	Academia Colombiana de Ciencias
Telfort, Renald	Haïti	retelf@hotmail.com	Ministry of education, Haïti
IAP NETWORKS / ASIA FASAS-AASA			
Rastegar, Tahereh	Iran	rastgar@iust.ac.ir	Iran University of Science and Technology (IUST)
Gopal, Krishna	India	krishna@ncra.tifr.res.in	Tata Inst. of Fundamental Research (India)
Ji, Mingze	China	mzji@dem.ecnu.edu.cn	
Mohd. Ishak, Noriah	Malaysia	norwmu@hotmail.com	University Kebangsaan Malaysia Bangi, Selangor, Malaysia
Peers, Shelley	Australia	shelley.Peers@science.org.au	Director, Primary Connections Australian Academy of Science
Meylan, Richard	New	Richard.Meylan@royalsociety.or	The Royal Society of New Zealand

	Zealand	g.nz	
Soomro, Manzoor Hussain	Pakistan	chairman@psf.gov.pk	Pakistan Science Foundation
Yu, Dongchuan	China	dcyu@seu.edu.cn	Research Center for Learning Science, Southeast University, Nanjing China
IAP NETWORKS / EUROPE ALLEA			
Dombrowski, Tilo	Germany		
Hertel, Ingolf	Germany		
Klein, Rüdiger	ALLEA	rudiger.klein@allea.org	Executive Director, ALLEA
Peeters, Marieke	Netherlands		
Robin, Nicholas	Switzerland		
Arnon, Ruth	Israel		
Brunori, Mauricio	Italie		President EMAN, Accademia dei Lincei
Csapo, Beno	Hungary		
Figdor, Carl	Netherlands	c.figdor@ncmls.ru.nl	The Science Hub of the Radboud University Nijmegen
Galchenko, Maksym	Ukraine		
Holmgren, Sven-Olof	Sweden	soh@fysik.su.se	Royal Swedish Academy of Sciences
Hunger, Hermann	Austria		
Jokic, Stevan	Serbia	sjokic@vin.bg.ac.rs	Serbian Academy of Sciences and Arts
Kranjc, Andrej	Slovenia	andrej.kranjc@sazu.si	Slovenian Academy of Sciences and Arts
Larsson, Pia	Sweden		
Lopp, Margus	Estonia		
Pascucci, Anna	Italy		
Pupovci, Dukagjin	Kosovo	dpupovci@gmail.com	Kosova Academy of Sciences and Arts
Radonjic, Dragan	Montenegro		
Sjøberg, Svein	Norway	svein.sjoberg@ils.uio.no	Norwegian Academy of Science and Letters
Vecchio, Giancarlo	Italy		Accademia dei Lincei, Roma
Wanders, Elsa	ALLEA	elsa.wanders@bureau.knaw.nl	Secretary, ALLEA
OTHER PARTICIPANTS			
Amatore, Christian	France	christian.amatore@academie-sciences.fr	Délégué à l'éducation et la formation, Académie des sciences, France
Person, Xavier	France	xavier.person@fondation-lamap.org	International relations, Fondation La main à la pâte
Quéré, Yves	France	yves.quere@academie-sciences.fr	Académie des sciences, France, Former IAP Co-Chair
Tran, Thanh-Son	Vietnam	son.tran@tours.inra.fr thanhsonbio227@yahoo.fr	Institut national de recherche agronomique, France
Yeomans, Emily	UK	E.Yeomans@wellcome.ac.uk	Project Manager, Education, Wellcome Trust
LOCAL FINNISH PARTICIPANTS			
Aksela, Maija	Finland	maija.aksela@helsinki.fi	Professor, Director of LUMA

Hellemaa, Pirjo	Finland	pirjo.hellemaa@helsinki.fi	University Lecturer, Deparment of Geosciences and Geography, University of Helsinki
Hopea, Armi	Finland	armi.hopea@helsinki.fi	Staff of LUMA
Lampiselkä, Jarkko	Finland	jarkko.lampiselka@helsinki.fi	University Lecturer, Deparment of Teacher Education, University of Helsinki
Lundell, Jan	Finland	jan.c.lundell@jyu.fi	Professor, Department of Chemistry, University of Jyväskylä
Martio, Olli	Finland	olli.martio@acadsci.fi	General Secretary, Finnish Academy of Science and Letters
Oikkonen, Juha	Finland	juha.oikkonen@helsinki.fi	Professor, Vice Director of LUMA
Oivanen, Mikko	Finland	mikko.oivanen@helsinki.fi	Professor, Department of Chemistry, University of Helsinki
Pernaa, Johannes	Finland	johannes.pernaa@helsinki.fi	Researcher, Department of Chemistry, University of Helsinki
Rantaniitty, Toni	Finland	toni.rantaniitty@helsinki.fi	Staff of LUMA
Tolppanen, Sakari	Finland	sakari.tolppanen@helsinki.fi	Staff of LUMA
Tolvanen, Simo	Finland	simo.a.tolvanen@helsinki.fi	Staff of LUMA
Tähkä, Tiina	Finland	tiina.tahka@oph.fi	Counsellor of Education, National Board of Education
Vihma, Lauri	Finland	lauri.vihma@helsinki.fi	Coordinator of LUMA
Vilhunen, Anna-Sofia	Finland	anna-sofia.vilhunen@helsinki.fi	Staff of LUMA

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